eRHIC – Future Electron-Ion Collider at BNL

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Abstract. The work on the detailed design of electron-ion collider, eRHIC, on the basis of existing RHIC machine is underway. eRHIC aims to be an instrument for the exploration of important QCD aspects using collisions of polarized electrons and positrons on ions and polarized protons in the center of mass energy range of 30-100 GeV, with a luminosity of 10^{32}-10^{34} $cm^{-2}s^{-1}$ for e-p and 10^{30}-10^{32} $cm^{-2}s^{-1}$ for e-Au collisions. An electron accelerator, which delivers about 0.5A polarized electron beam current in the electron energy range of 5 to 10 GeV, would be constructed at BNL, near the existing RHIC complex and would intersect an ion ring in at least one of the available ion ring interaction regions. One design option considers the circular electron machine based on the accelerator technology similar to that of storage rings at the e+-e- B-factories. Another pursued design option employs an energy recovery linac for electron acceleration. This option paves way to higher luminosities but meets challenges of developments of high current electron polarized source and high beam power ERL technologies. To maximize the collider luminosity certain upgrades are considered for RHIC ion rings.

Keywords: particle collider; polarized beams; energy recovery linac
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ERHIC DESIGN FEATURES

Initial design of future electron-ion collider eRHIC has been developed by collaboration of accelerator scientists from BNL, MIT-Bates, BINP and DESY [1]. The design extends capabilities of existing heavy ion collider RHIC at Brookhaven National Laboratory by adding an electron accelerator which will provide polarized electron (and positron) beams for collision with ions and polarized protons circulating in RHIC. RHIC has interaction regions where no detectors for ion-ion collision have been installed and which are available for possible utilization for electron-ion collisions. The electron accelerator will produce the electrons in the energy range from 5 to 10 GeV. It will lead to the center of mass energy range from 30 to 100 GeV for electron-proton collisions.

There are two independent design options of eRHIC, which differ by the design of the electron accelerator. In the *ring-ring* scenario the electron beam circulates in a storage ring, which intersects an existing ion ring in one point. The injection into the storage ring is done from a recirculating linac injector which accelerates the electron beam up to 10 GeV energy (no additional acceleration is done in the storage ring). The electron beam is produced by a polarized electron source and hence it is initially polarized. Depolarization effects in the storage should be minimized to keep the electron beam polarization at the high level of >70% with storage times of order of several hours. It provides strict tolerances on the beam vertical orbit errors. Nevertheless at some energies, corresponding to spin resonance conditions, the polarization can not be preserved.

Unpolarized positrons are produced in a conversion system which is a part of the injector. After production, the positrons are accelerated to 10 GeV and injected into the storage ring in the same way as the electrons. While circulating in the storage ring the positron beam acquire the polarization due to synchrotron radiation self-polarization process. Effective self-polarization with short enough polarization time (~15min) is possible at 10 GeV energy. But since the polarization time increases sharply as the beam energy decreases, the use of polarized positrons in the current design is limited to 10 GeV.

On the values of electron energy and required electron current (0.5-1 A) the eRHIC electron storage ring is comparable with the storage rings in B-meson factories. Many design features and technology developed and used in the B-factories can be effectively applied for the eRHIC electron ring. Thus the electron accelerator design for ring-ring option is based on currently available accelerator technology and does not require extensive R&D.

Figure 1 shows another design option which is under development, the *linac-ring* option [2]. This option uses fast developing energy recovery linac technology. High current polarized electron beam accelerated to collision energies by a superconducting energy recovery linac (ERL).

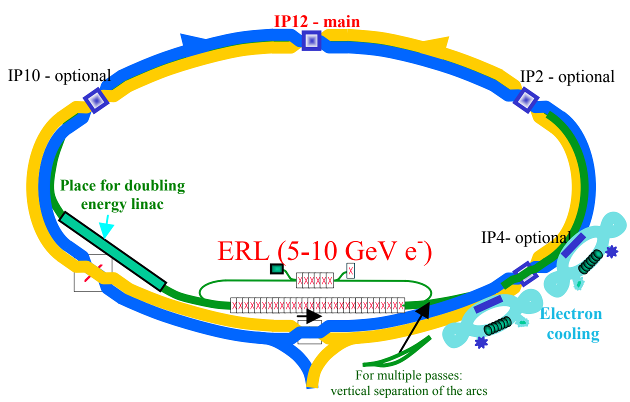

FIGURE 1. Linac-ring design option of eRHIC uses energy recovery linac as the electron accelerator.

Two recirculating passes of the ERL are located in the RHIC tunnel together with Blue and Yellow ion rings. There might be more than one electron-proton collision points in this design. The handling of electron polarization and the interaction region design are simpler in the linac-ring option. An IR design with round beam collisions can be realized in this case.

The disadvantage of the linac-ring option is the exclusion of positron beams.

The major challenge for the linac-ring design is to achieve high, polarized, electron currents of several hundred milliamps from the polarized injector and the ERL. This requires intense R&D to develop and to test technologies for high-current polarized electron sources and high power energy recovery linacs.

ACHIEVABLE LUMINOSITIES

Figure 2 below shows the luminosities achievable in linac-ring and ring-ring options as the function of proton beam-beam parameter. Electron cooling is under consideration in order to reduce transverse emittance of the proton beam. Even with the cooling the luminosity for ring-ring option do not exceed 10^{33} $cm^{-2}s^{-1}$. Main luminosity limitation comes from the beam-beam effects. In the linac-ring option the beam-beam tune shift for the electron beam does not limit the luminosity, since each electron bunch experiences only one collision. An e-p luminosity beyond 10^{33} $cm^{-2}s^{-1}$ might be achieved in this design, with the luminosity limit coming from the maximum achievable proton (ion) beam intensities, as defined by electron cloud related effects and the heating of ion ring cryogenic vacuum pipe. The luminosity in the linac-ring version may benefit considerably from the application of electron cooling.

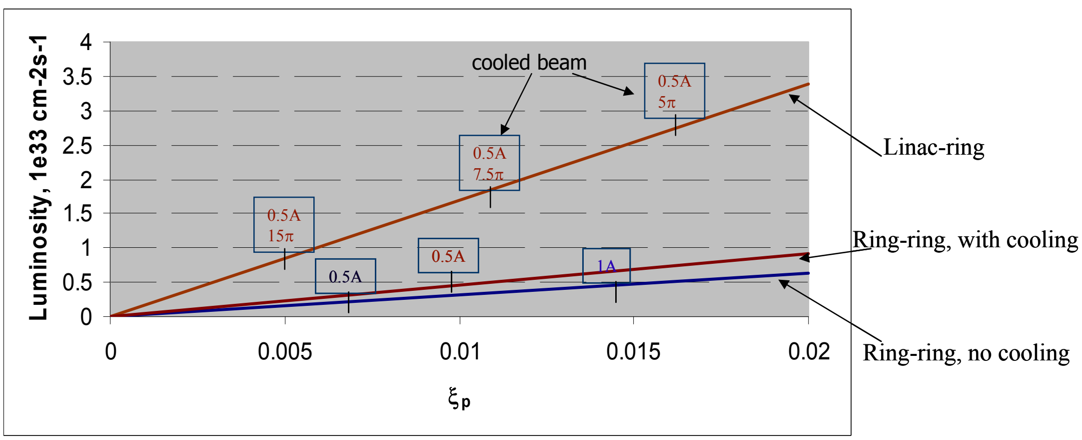

FIGURE 2. Comparison of luminosities versus proton beam-beam parameter for linac-ring and ring-ring option, with and without electron cooling of the proton beam. 360 bunches are assumed in the proton ring with 1e11 proton per bunch. Markers demonstrate the luminosities for indicated electron current and indicated proton normalized transverse emittance.

REFERENCES

1. "eRHIC Zeroth-Order Design Report", BNL C-A/AP Note 142, 2004. http://www.agsrhichome.bnl.gov/eRHIC/eRHIC_ZDR.htm

2. V.Litvinenko, et al, Appendix A in reference 1.